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REVIEWS

The Relative Length of Day and Night

Garner and Allard's discovery of the influence of the relative length of day and night on the growth and reproduction of plants[1] adds a hitherto unrecognized factor to the environmental complex. The possibilities which this factor offers for ecological research appear more promising than almost any since Briggs and Shantz found the wilting coefficient of soils.[2]

The importance of light has of course long been recognized, and a few years ago Briggs and Shantz found in studying transpiration that solar "radiation may then be looked upon as the primary causative factor in cyclic changes."[3] Klebs, while working on the problem of rhythm, succeeded in making beech grow continuously in artificial light.[4] Bonnier[5] found that continuous illumination (artificial), as compared with alternate light and darkness, produced marked changes in the form and structure of the plant. The green color was made much more intense, extending to the stems, and the flowers were more highly colored. The surprising part of Garner and Allard's discovery is therefore not that light plays such an important part, but that the relative length of day and night should exercise such an influence on growth and reproduction.

Garner and Allard do not attempt to explain the physiological causes of what they found. It would be interesting to know just what influence the length of daylight has upon the metabolism of the plant to cause such profound changes in vegetative growth and flowering. The effect appears to be the same as variations in the nitrogen and carbohydrate supply. We know that a large supply of nitrogen induces vegetative growth at the expense of flowering, and that a low nitrogen and high carbohydrate supply reduces growth in size and stimulates flowering.[6] Is it possible that the daylight causes an increased absorption of nitrogen? The similarity of the two effects opens up a most promising field of study.

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[1] Garner, W. W., and Allard, H. A., "Effect of Relative Length of Day and Night and other Factors of the Environment on Growth and Reproduction in Plants," Jour. Agr. Res., 18: 553–606, March, 1920.

[2] Briggs, L. J., and Shantz, H. L., "The Wilting Coefficient for Different Plants and its Indirect Determination," U. S. Dept. Agr. Bur. of Plant Industry, Bul. 230, 1912.

[3] Briggs, L. J., and Shantz, H. L., "Hourly Transpiration Rate on Clear Days as Determined by Cyclic Environmental Factors," Jour. Agr. Res., 5: 583–649, Jan., 1916.

[4] Klebs, G., "Ueber der Rhythmik in der Entwicklung der Pflanzen," Sitzungsberichte der Heidelberge Akademie der Wissenschaft, 23 Abhandlung, 1911; "Ueber das Treiben der einheimischen Baume, speziell der Buche," Abh. d. Heidelb. Akad. d. Wiss. Math.-Naturw. Kl., 3 Abhandl., 1914, Rev. Plant World, Vol. 18, No. 1, p. 19, 1915, Forestry Quarterly, Vol. 13, No. 3, p. 382, 1915, and Vol. 14, No. 1, pp. 83–85, 1916.

[5] Bonnier, Gaston, "Le Monde végétal," E. Flammarion, Paris, 1914 (see pp. 318–320).

The major part of the experiments described consisted of artificially reducing the length of the day by placing the tested plants in specially constructed darkened houses for a certain part of the early morning and late afternoon, while control plants were left out of doors continuously. The plants tested were several varieties of soy bean and of tobacco, aster (*A. linariifolius* L.), climbing hempweed (*Mikania scandens* L.), beans, ragweed (*Ambrosia artemisiifolia* L.), radish, carrot, lettuce, *Hibiscus moscheuotos* L., cabbage, violets (*Viola fimbriatula* Sm.), and early goldenrod (*Solidago juncea* Ait.). The length of day given the test plants was generally from 9 A.M. to 4 P.M., though some had as long an exposure as from 6 A.M. to 6 P.M., and others as short as from 10 A.M. to 3 P.M. With the plants which bloom in the shorter days of late summer the artificially shortened days produced blooming in the early summer. This was particularly true of the soy beans and Maryland Mammoth tobacco. Connecticut broadleaf tobacco on the other hand blossomed at nearly the same time in the test plants and controls. With the climbing hempweed, which normally blossoms from July to September, the test plants, exposed from 9 A.M. to 4 P.M., failed to blossom at all, while the controls behaved normally. With the radish, the test plants developed slowly and finally died; the same occurred with lettuce. In *Hisbiscus moscheuotos* and cabbage the test plants did not blossom, while the controls did. The test plants of violets produced both purple petaliferous and cleistogamous flowers, the controls only the latter kind. With early goldenrod both test plants and controls blossomed at the same time. In general the vegetative growth of all plants was proportional to the length of exposure to light.

The experiments show that for the species studied, flowering and fruiting can be attained only when the length of day falls within certain limits. Some species and varieties respond to short days, and still others respond to all lengths of the day prevailing in the latitude of Washington.

Confirmation of the outdoor experiments was secured in winter by using electric light of comparatively low intensity in a greenhouse to prolong the day. In spite of low intensity of the light—bulbs of 32 candle power were used—a number of plants which did not blossom in the control house were made to flower. Among these were *Iris florentine,* spinach, cosmos, radish, and violets. Plants requiring short days for flowering, such as Maryland

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[6] Kraus, E. J., ad Kraybill, H. R., "Vegetation and Reproduction with Special Reference to the Tomato," Oregon Exp. Sta. Bull. 149, 1918. Bot. Abs., Vol. 1, entry 1402, Jan., 1919.

Mammoth tobacco, *Freesia refracta,* lima beans, and beggar-ticks (*Bidens frondosa* L.), blossomed in the control house but not in the one which was illuminated. Strangely enough the cosmos in the lighted house averaged 60 inches in height as against only 30 inches in the control house—a remarkable stimulus for light of low intensity!

Extreme variations in soil moisture were found to have no effect on the time of flowering. Reducing the intensity of the light by artificial shading was also ineffective. It was also found, curiously enough, that exposing plants to two periods of illumination daily was vastly less effective in inducing blossoming than a single exposure.

The authors, on page 603, tentatively formulate the following principle: "Sexual reproduction can be attained by the plant only when it is exposed to a specifically favorable length of day (the requirements in this particular varying widely with the species and variety), and exposure to a length of day unfavorable to reproduction but favorable to growth tends to produce gigantism or indefinite continuation of vegetative development, while exposure to a length of day favorable alike to sexual reproduction and to vegetative development extends the period of sexual reproduction and tends to induce the 'ever-bearing' type of fruiting."

The bearing of the experiments on plant distribution is evident. Plants requiring the short days of late summer for flowering and fruiting are unable to establish themselves in northern latitudes because of the low temperature accompanying the favorable length of day. Similarly, plants requiring long days cannot flower in the tropics. This information will unquestionably be of great practical value in agriculture, enabling the better selection of plants capable of producing the maximum amount of vegetable matter or of seed.

The work of Garner and Allard tends to explain many phenomena which were difficult to understand without presupposing an inherent rhythm in plants. For example, the autumn of 1914 in northern Maine was particularly warm, without night frosts; and yet the leaves took on their autumn coloring and fell from the trees, probably on account of the short days. On the other hand there are contradictory phenomena which are probably explainable on the grounds of the wide range of daylight required by certain species and the influence of temperature within this range. For example, living plants of Lapland rhodendron (*Rhododendron lapponicum*) and *Diapensia lapponica* which were found on Mt. Marcy in full flower on June 5, 1919, were collected and brought to the Brooklyn Botanic Garden. These same plants flowered again on April 20, 1920, at a considerably shorter length of day than in their native surroundings.

The results of the experiments above reviewed can readily be supplemented by data on the time of flowering of different plants in different latitudes. The length of day is already known, and can be found in the

"Smithsonian Contributions to Knowledge," V. 21, pp. 114–119, 1876, which gives tables showing the time of sunrise and sunset at ten day intervals through the year for various latitudes in North America. There is rather scanty data on the exact dates of blooming, particularly for spring plants which under favorable conditions bloom again in the fall.

Dr. C. V. Piper, in charge of Forage Crop Investigations in the Bureau of Plant Industry, is much interested in Garner and Allard's discovery, and has written to the reviewer that this "opens a very fascinating new field for ecological work and one in which it seems to me your society (the Ecological Society) might well undertake the systematic collection of data." He suggests for each species of plant the following list of observations:

Location
Altitude, if considerable
Date of first blossom
Date of full bloom
Date of last blossom
Percentage of fruit to blossom—small—medium—large
Date of second flowering in fall, if it occurs.

Since such data will be of unquestionable value in determining the influence of the relative length of day and night on the reproduction of plants, it is hoped that as much as possible will be collected and sent to the authors of the above paper.

Is it not more than probable that the relative length of day and night influences animals as well as plants, and has a direct bearing on such phenomena as periodic hibernation and migration. Garner and Allard's work therefore opens a fascinating field not only for the botanist, but for the zoologist.

BARRINGTON MOORE